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Novel Thermal Control Approaches for Mars 03/05 Athena Rover

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ABSTRACT

The long term survival of Mars landers and rovers depends critically on the thermal control of their batteries, electronics and the science equipment. The ambient atmospheric temperatures on Mars range from +10 °C during the day, to as low as –90 °C at night. Various passive thermal control techniques have been used in past Mars missions to keep the temperatures of the electronics, science equipment, and batteries in landers and rovers within their acceptable limits. Of all the equipment used on the Mars 03/05 Athena rover, the Lithium-Ion secondary battery is the most temperature sensitive. Batteries can age prematurely at elevated temperatures (above 40 °C) and electrolytes can freeze at low temperature (below –30 °C). The temperature limits of the Athena rover electronics and science is –40 to +40, whereas the Raman spectrometer optical assembly CCD operating limit is –20 to -40 C.

Novel thermal control approaches developed for the Mars 03/05 Athena rover for keeping its equipment temperatures within their allowable limits will be described in the presentation. The thermal design relies on several new thermal control technologies such as phase change material (PCM) thermal storage, variable conductance loop heat pipe (LHP), and heat switch. To keep the battery temperatures above the lower limit, the system uses the PCM thermal storage module to store heat and a loop heat pipe (LHP) to transfer heat between a set of Radioisotope Heater Units (RHUs) and the battery. To keep the battery temperature below the upper limit, a thermal control valve in the LHP opens to redirect the working fluid to an external radiator where excess heat is dumped to the atmosphere. A wax actuated heat switch keeps the Raman spectrometer optical assembly CCD from going below –30 C during nightime operations. The heat switch thermally disconnects the instrument from an external radiator whenever the instrument temperature falls below –30 C. The PCM thermal storage module was designed and fabricated using dodecane paraffin wax (melting point, –10.5 °C) as the phase change material. This design also incorporates a lightweight aluminum jacket and carbon fibers interspersed within the PCM to provide thermal and structural reinforcement to the module. A miniature variable conductance loop heat pipe was designed and fabricated. A thermal control valve integrated in the LHP provides the variable conductance.

The results from an experimental simulation of the Mars '03/'05 rover thermal performance in the Martian environment will also be presented at the workshop. Tests are currently being performed for various internal configurations of the PCM and LHP arrangements including worst case hot and cold cases. Based on the results of these tests, the Mars '03/'05 rover thermal design development will be finalized. Many lessons are being learned during the development and implementation of these thermal technologies for Mars rover battery thermal control. Recommendations for the design and operation of loop heat pipe and phase change material thermal energy storage systems for future space missions will be made in the presentation.

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